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Thermal neutron simulation response of GEM-based detectors with the FLUKA-MC package

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ABSTRACT

In the current work, we demonstrate the possibility of using the FLAIR (an advanced user friendly interface) that can be employed for building the radiation simulator via inserting the basic parameters in it. Generally, the FLAIR interface is utilized by the user for FLUKA MC package to assist in the editing of the input files, execution of the simulation code and for the visualization of the output data. The current work describes some of the features of the radiation simulator which a general user has to handle, while using the FLUKA MC code. Further it explores the basic structure of the FLAIR simulator generator. In the last section the results of a simulation test obtained for the thermal neutrons detection via Boron-coated (gas electron multiplier) GEM-detector using the FLUKA-MC code have been described. The detector efficiency ~4.7% and ~6.03% has been evaluated for the forward- and backward detector setup, respectively. The current simulation results have been compared with the experimental findings which reveals a close agreement. The obtained results revealed that the GEM-detector can detect the thermal neutrons efficiently.

1. Introduction

Monte Carlo (MC) computer simulations are widely considered as useful tool used to model and simulate the interaction of particles with matter. Consequently such computational packages are getting much attention among nuclear physics, particle physics and in high energy physics communities. At the present times, mainly three kinds of Monte Carlo packages are being in use, which include the GEANT4 MC package [1], the MCNPX MC package [2] and the FLUKA MC package [3,4]. All of these soft-wares include a complete range of functionality including particle tracking, geometry, physics models and hits.

Among these packages, the FLUKA MC software ("Fluka") means the fully integrated particle physics Monte Carlo simulation software package [4]. This package has been developed since 1989, available from the official Fluka website [5] and authorized mirror sites. The FLUKA MC package has been built by the Fluka core code and by the Fluka User Routines. Here the User Routines means the set of subroutines which are collected in the usermvax section (which serve as a directory) of Fluka and build the part of the standard distribution of Fluka.

Fluka is a general purpose simulation tool utilized for the calculations of particle transport and interactions with matter, covering an extended range of applications spanning from proton and electron accelerator, shielding to target design, calorimetry, activation, dosimetry, detector design, Accelerator Driven Systems, cosmic rays, neutrino physics, radiotherapy, etc. [4].

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In the past, thermal neutron detection has been remained a subject of great interest among the high energy physics and nuclear physics community. Among gaseous detectors, ^{3}He filled detector is considered very useful option both for the thermal and low energy neutron detection. However, the diminishing inventory and limited natural abundance of ^{3}He gas on Earth demand the adoption of new technologies for the detection of thermal neutrons, especially in security applications [6] and scientific research [7], where for the large volume detector require many liters of ^{3}He.

In the present timings, thermal neutron converters coupled to gaseous detectors are considered as one of the most important topics due to the necessity to find ^{3}He alternatives [8–10]. To our knowledge, several papers have been published about the study of thermal neutron interaction with solid boron converter and in one of the work even an analytical description of this interaction has been estimated [7].

The present work is an attempt to find ^{3}He alternative detectors for thermal neutron study. For this purpose, we selected Boron-coated gas electron multiplier (GEM) as candidate for thermal neutron detection. Also we try to focus and compare our findings with the previous experimental findings for low energy neutron detection.

Upon considering the advantageous features of Fluka package, we decided to install it on our work-station at our lab oratory and made an attempt to investigate the response of thermal neutrons impinging onto the Boron-coated gas electron multiplier (GEM) detector. For the code development purpose, we dedicated one Pentium 4 personal computer running via scientific linux version 6.0 [11], with the GCC complier 4.6.4 installed. In the next step, we installed the flair-1.1-1 versions, with the latest version of Fluka-2011.2.17 software package with its low energy neutron physics available.

The second section describes some of the details of the FLUKA simulations package. The third section, reports about the detector configuration and about the incident thermal neutrons transportation. While the fourth section gives a discussion on the simulation results. Finally a conclusive summary of the obtained results has been given.

2. FLUKA MC package and the simulation test

FLUKA has been maintained jointly by INFN (Italian National Institute for Nuclear Physics) and by CERN (European Organization for Nuclear Research). FLUKA is a general-purpose Monte Carlo simulation tool for modelling the interaction and transport of about 60 different particles from hadrons and heavy ions to electromagnetic radiations, with energy ranging from a few keV (or thermal energy for neutrons) up to GeVs in any solid, gaseous and liquid material [3,4,12].

This MC package is similar to MCNP (Monte Carlo Team, 2003) and other multi-purpose codes, in which the user has to provide geometry, material, source position or energy and scoring type of the specific problem, which are called cards [12].

In order to estimate the response function of Boron-coated gas electron multiplier (GEM) as accurately as possible, which is the main theme of the work, one has to locate the interactions site of the incident low energy neutron and their corresponding energy depositions [12]. Thus such implications have been addressed in the present simulation carried out via FLUKA MC code. For the present work, low energy neutron transport package has been activated and employed for thermal neutron detection.

2.1. Concept of FLUKA-FLAIR simulator

FLAIR is written entirely with python and Tkinter that allows an easier portability across various operating systems and great programming flexibility with focus to be used as an Application Programming Interface (API) for FLUKA [4]. In general, FLAIR operates with the concept of the "FLUKA projects". A FLAIR-FLUKA project is a structure containing the following detailed information [13,14]:

- General project information like title, notes, override formatting options for the input file.
- Links to the filenames for the default input, optional geometry files and executable.
- Maintain a list of geometry debugging regions.
- Links to auxiliary Fortran files and libraries for compiling a user FLUKA executable if necessary.
- List of runs: A project can contain multiple runs based on the same input file by overriding the default preprocessor defines, title, random seed, number of start.
- Particles, run cycles and executable file.
- List of output files and rules for merging the output of scoring cards.
- List of user defined plots, for Geometrical configuration, all USRxxx cards (that serve as the user defined scoring cards), RESNUCLEi (that scores residual nuclei after inelastic hadronic interactions) and visualization of the input file information.

All of such information is stored in a text file with the extension. FLAIR, and is "editable" with the FLAIR program.

Additionally FLAIR is capable to read and write all formats recognized by FLUKA, however internally it works always in the name-based format, and treats the input as a list of extended cards. The default format for saving is always kept fixed with names for the input and free with names for the geometry. Moreover the user of the program, can override the default exporting format by using the appropriate FLUKA cards [2].

Upon considering such useful features of FLAIR, we have used it for the evaluation of the current work.

2.2. Thermal neutrons detection mechanism via ^{10}B-converter

As neutrons are charge-less particles, thus their detection can only be performed after their interaction with a suitable material, known as converter. The converter has the role of generating ionizing particles, which are easily detectable. Since such converter material plays a crucial role in the detecting system, its choice requires special